Space Weather Technical Forecast

Issued on Friday, 15 September 2023 at 01:15 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Daily Chance of R1. Slight Chance G1 Minor Storms at first, rising to Likely late Day 2 and then Chance Day 3, before falling after that.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate in the past 24 hours. Three M-flares of note occurred; the largest came from sunspot region AR3429 and peaked at M2.4 at 14/2126 UTC with another M1.9 from the same region at 14/1931 UTC. The third was a large, long-period M1.4 flare from an energetic filament eruption in the northwest quadrant, immediately northeast of the largest sunspot region on the disc, AR3423. This event has been confirmed as becoming interplanetary in STEREO A coronagraph imagery, with some component of this expected to be earth directed. Current analysis suggests arrival sometime in the UTC afternoon/evening of Day 2 (16 Sep).

There are 8 sunspot regions on the visible disc. AR3423 remains the largest, but has lost some intermediate spots in the past 24 hrs, however its trailing spot has split into two larger penumbral spots. AR3429 is the next largest group and has shown some increasing magnetic complexity, with a delta spot forming in the large central penumbral region. This region also exhibits a north-south magnetic configuration. Other larger bipolar regions, AR3425 and AR3430, have both continued to show fading of intermediate spots and a general decay with time. Other spots on the disc are generally smaller and simpler.

As mentioned above, the CME tied to the aforementioned M1.4 filament eruption has an expected arrival during the second half of Day 2 (16 Sep). There have been a couple of other filament disruptions on the Earth-facing disc in the past 12 hrs, with imagery and analysis pending.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by ACE and DSCOVR at L1, were initially indicative of a descent into a slow regime, but with a notable reversal starting around 14/0300UTC, likely a CIR ahead of what is likely to be coronal hole fast wind 44/+ (although the phi angle has yet to settle).

Solar wind speeds initially were at Slow/Ambient levels in the upper-300 km/s, before rising more sharply to an Elevated high around 500 km/s through the UTC day. The solar wind density was initially stable near its long-term average of single figures ppcc, but this rose to a peak in the low teens by mid-morning before moderating slightly. Further variability later in the UTC day briefly saw above average figures, peaking at 27 ppcc. The IMF was initially around 10nT, falling back to around 6nT during the UTC morning, before then recovering back to earlier values later in the day. Towards the end of the period it became more variable. The north-south component, Bz, was variable, with a maximum scope of -9 and +7nT, with much of the UTC day spent around +5nT. The phi angle was mainly positive (away from the Sun) at first, but became more consistently negative (towards the Sun) later in the day.

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The net effect of the above solar wind measures has seen Quiet to Active geomagnetic activity (Kp2-4).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux has been at Background levels.
GOES16 high energy (greater than 2MeV) electron flux was at Normal Background levels. The associated 24-hour fluence was well below the Active threshold, with 6.2e6 integrated pfu observed at 15/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: There is a daily Chance of M-class flares, mainly from AR3429 near centre disc, as well as from AR3423. AR3323 should leave the Earth-facing side over the coming UTC weekend, but the flare risk may be maintained by the return of Ex-AR3413 in the east, which may be the source for some large recent far-sided CMEs and, by inference, large flares.

Solar Wind / Geomagnetic Activity: A CME that left the Sun on 11 September may give a glancing blow at Earth later Day 1 into Day 2 (15-16 Sep), however, any potential effects at Earth are expected to be small if it does arrive. The CME from the M1.4 filament eruption mentioned above has been analysed to arrive during the UTC afternoon/evening of Day 2 (16 Sep), with Likely G1 Minor Storm intervals (Kp5).

Coronal hole fast wind influence from CH44/+ is expected to be imminent, with speeds at Elevated levels initially, then perhaps to Strong levels by later Day 1 or Day 2 (15-16 Sep) as CH47/- takes over. Speeds may then begin to slowly ease to round-out the current forecast period.

In summary, Active (Kp4) intervals and a Slight Chance of G1/Minor Geomagnetic Storm (Kp5) intervals are likely to continue for the first few days under the influence of coronal holes, with a Likely risk of G1/Minor Storm intervals later Day 2 and into Day 3 (16-17 Sep) with the expected CME arrival. Into Day 4 (18 Sep) there should be a diminishing Slight Chance of G1s, with geomagnetic activity expected to fall to Quiet to Unsettled levels (Kp1-3).

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a Slight Chance of an enhancement should any larger flares occur from AR3423 in particular.

High energy (greater than 2 MeV) electron flux is likely to be suppressed at Normal Background levels at GEO through much of the period, but perhaps with an eventual increase to diurnal High levels later on Day 4 (18 Sep). Overall, the 24-hour fluence is Expected to remain below the Active threshold throughout the period, with reducing confidence later in the UTC weekend.

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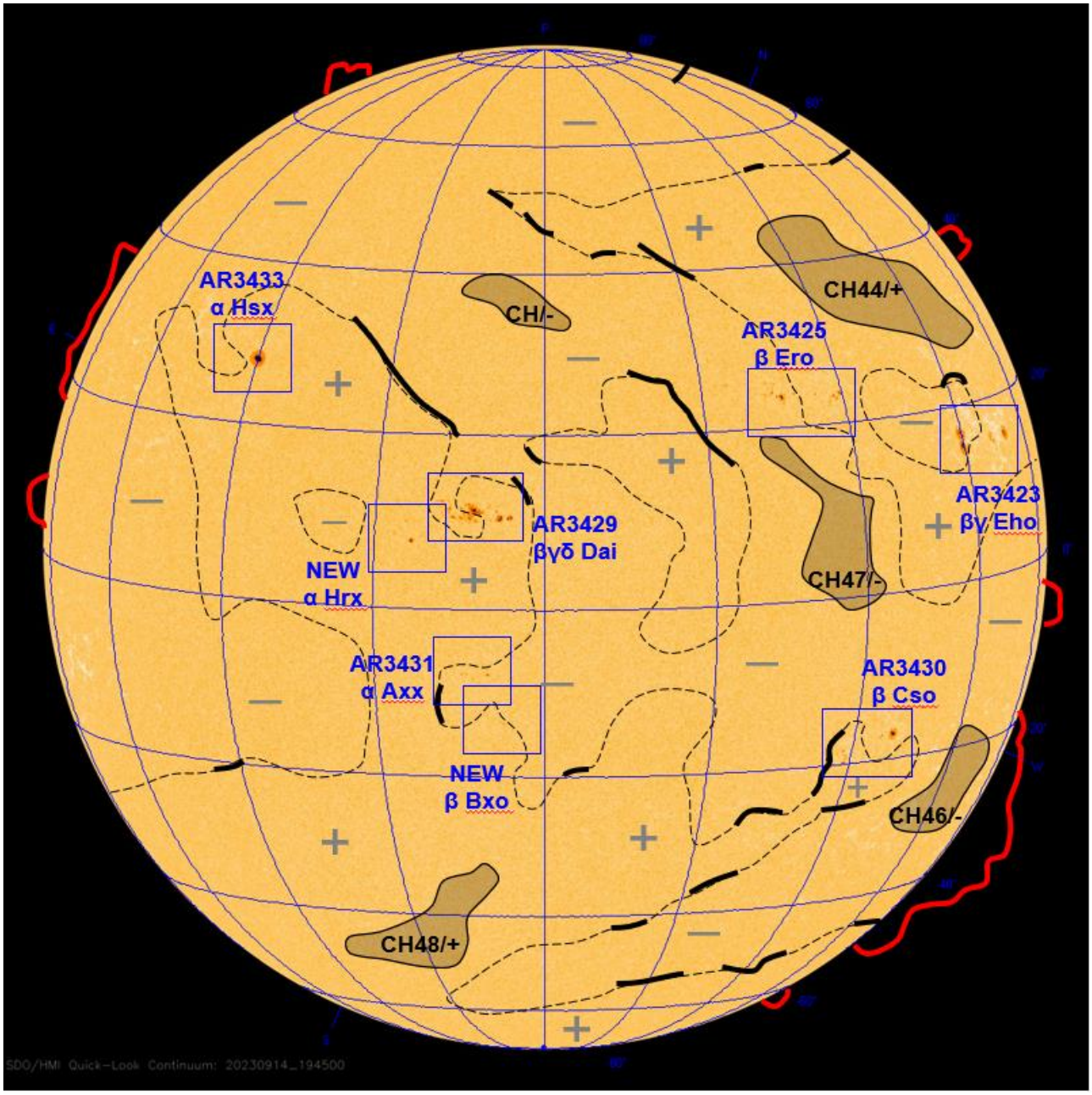
Figure 1. Solar Analysis Valid 14/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:
There are currently two CMEs in the forecast.

The first CME resulted from a filament eruption in the south-centre disc around 11/1400UTC. This gave a CME which appeared slow, largely southward-directed and relatively faint in imagery. Analysis has shown that this may give Earth a weak glancing blow possibly late on Day 1 or early Day 2 (15-16 Sep). Overall, little effect on geomagnetic activity is expected from this CMEs - if it arrives at Earth. The second CME was from a large filament eruption in the northwest around 14/0745 UTC, close to the sunspot region AR3423. This was rather tricky to analyse, with what appears to be an initial CME heading more westerly ahead of Earth, and then another overlapping CME which appears to be more Earth-directed. Current analysis suggests an arrival time of later in the UTC day on Day 2 (16 Sep), possibly pushing into early Day 3 (17 Sep).

Coronal hole fast wind enhancements are expected into the forecast period, and should predominate, at least at first. Firstly - and most likely - these should arise from CH44/+ in the northwest disc, though the MOSWOC Enlil model output continues to signal CH46/- in the southwest as the dominant feature. The onset of the influence from either or both these features is expected to now be imminent, with a long-lasting CIR already in course at L1, and with a subsequent increase in winds to Elevated levels (500-550km/s) now likely.

Later on Day 1, or maybe early into Day 2 (15-16 Sep), a connection to equatorial CH47/- in the western hemisphere is then likely. This feature was perhaps the source of some Strong solar winds (around 600km/s) on the last solar rotation, with a chance that winds may reach these levels later before slowly easing, though probably still at Elevated levels. Geomagnetic activity with this high-speed stream on the last rotation was muted (peaking at Kp3 - Unsettled), despite the Strong solar speeds observed. Negative polarity coronal holes are generally less geoeffective at this time of year, so similar Geomagnetic activity is probable again with this enhancement.

The above creates a somewhat complex and lower-than-average confidence forecast, with a variety of potential coronal hole and CME interactions. There is little assistance at present from Enlil modelling. G1/Minor Storm (Kp5) intervals are Likely later Day 2 and into Day 3 (16/17 Sep) with the CME arrival, with a Slight Chance before that. Otherwise, Active (Kp4) levels are most likely through the first few days of the forecast due to ongoing coronal hole influences, likely easing into Day 4 (18 Sep) to Quiet to Unsettled (Kp1-3).

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	10	60	40	10
Strong	G3	No	1	10	10	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
11/0209	Partial	Filament Eruption	SE	450 km/s	15/1800+/-9h	Limited shock. Low confidence on arrival.
14/1303	Partial	Filament Eruption	NW	559 km/s	16/1800+/-9h	Tricky to analyse with overlapping CMEs. Some Earth-directed component expected.

Figure 2a: MOSWOC Enlil model, showing CME arrival later on Day 2 (16 Sep). Note no real significant impact from earlier glancing blow CME on Day 1 (15 Sep).

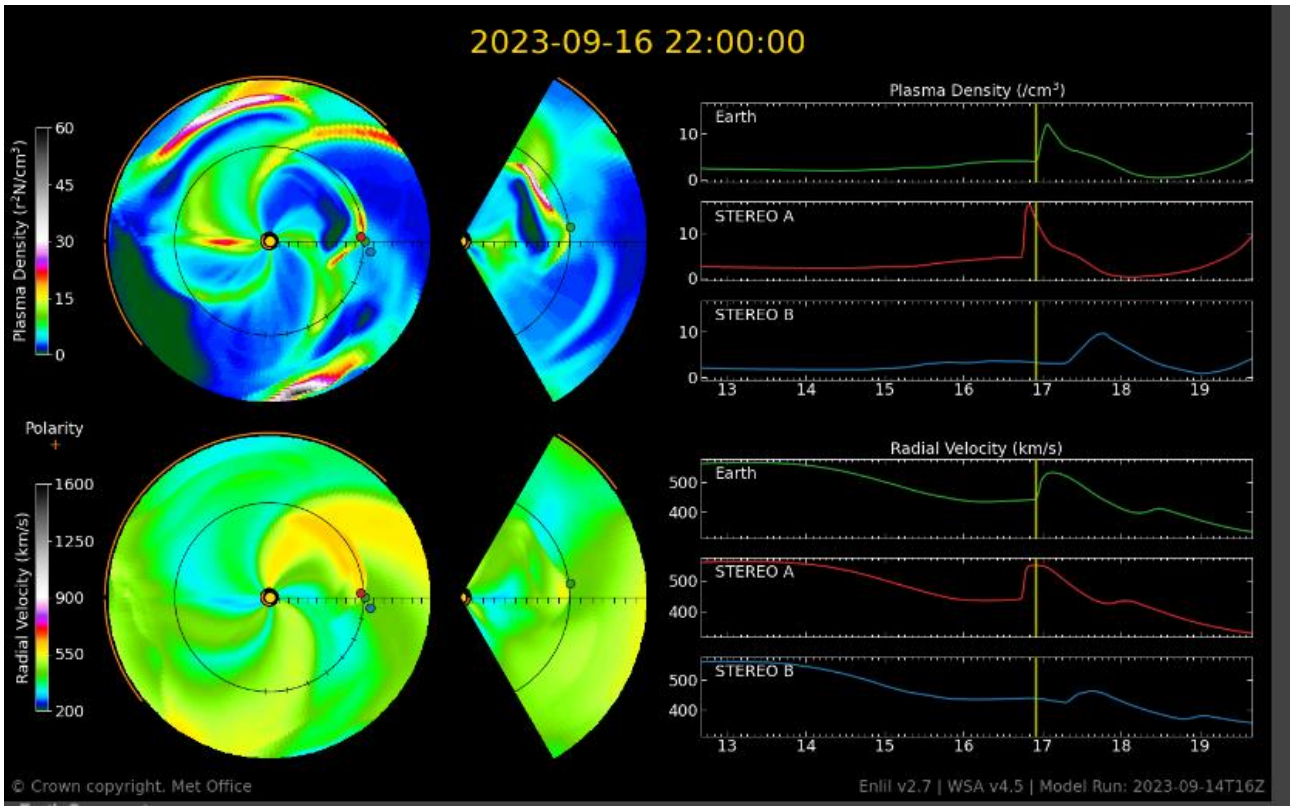

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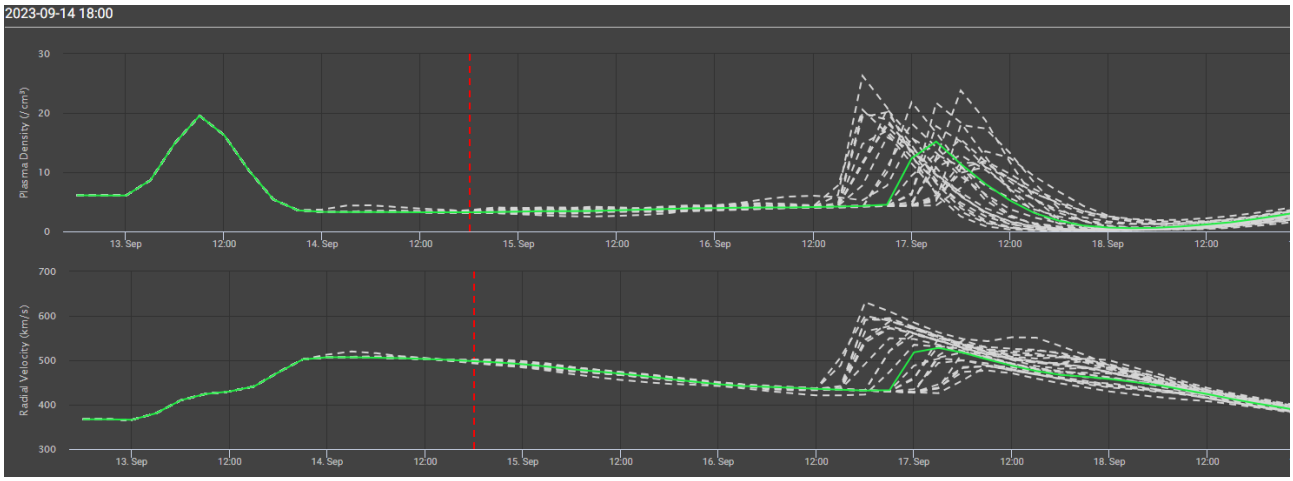
Figure 2b: MOSWOC Enlil Ensemble model, showing possible permutations in CME arrival time



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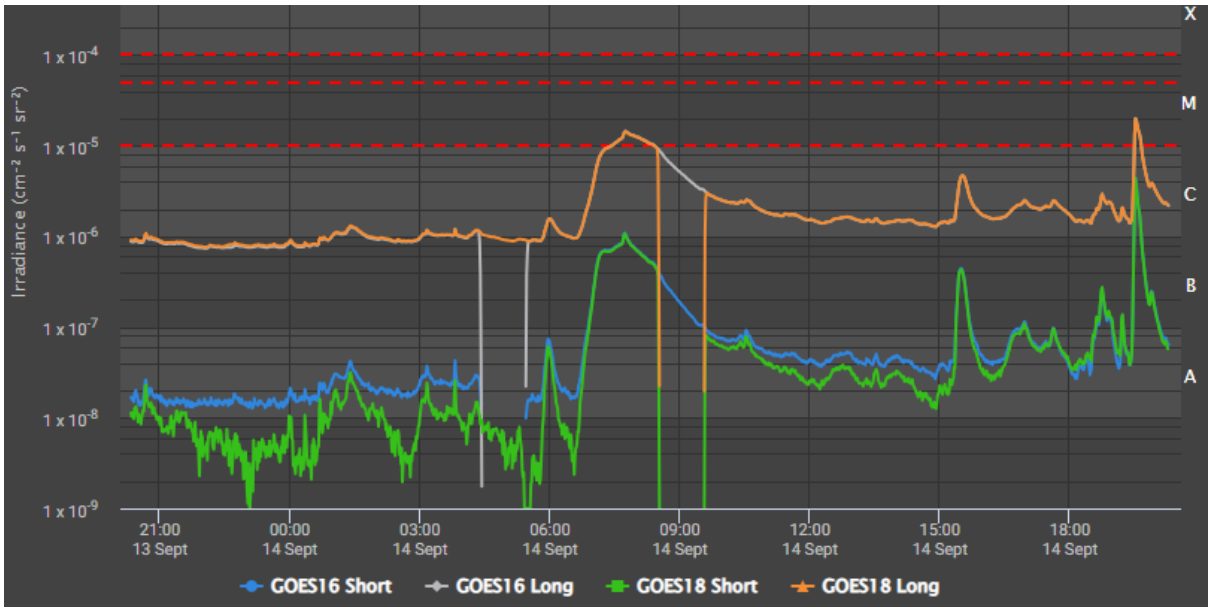
Radio Blackouts - X-Ray Flares:
There is a daily Chance of M-class flares and a Slight Chance of isolated X-class.

The main regions to watch are thought to be AR3423 in the northwest, and AR3329 that is now nearing centre-disc. The disc has seen three M-class flares in the past 24hrs. One of these was due to a filament lift-off near to AR3423, which while unlikely to happen again, still shows this region poses a risk. The other two M-flares have been of the more impulsive kind, both from AR3429, which has exhibited some increased magnetic complexity and growth with a delta spot briefly forming, as well as a north-south magnetic configuration. This region will be one to watch over the coming days as it progresses into the western hemisphere.

In terms of the forecast, AR3423 is expected to rotate off the visible disc through Day 2 or Day 3 (16-17 Sep), however, far-side sounding data suggests that a large region is expected to rotate over the eastern horizon roughly around the same time to mitigate against any otherwise declining risk. This arriving region is expected to be the returning Ex-AR3413, which was responsible for numerous M-class flares when last on the visible disc. A number of large, far-sided CMEs can likely be attributed to the region in the past several days, suggesting it is still active and has survived its transit of the far side.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	50	50	50	50
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: GOES 16 & 18 X-ray flux



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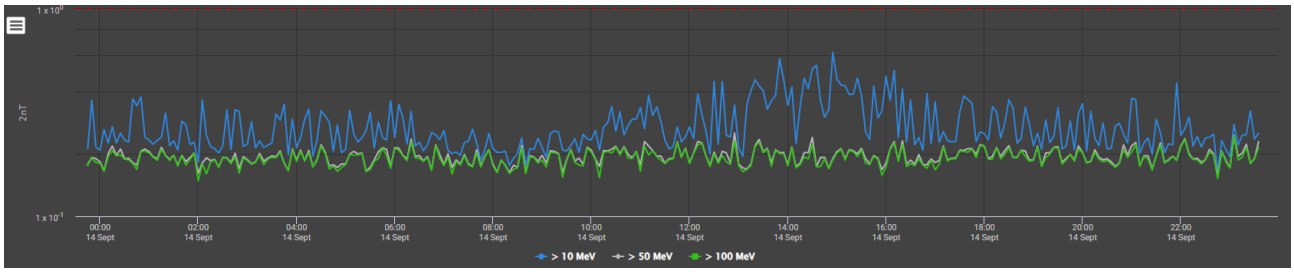
Solar Radiation Storms - (High Energy Protons):
The high energy (greater than 10MeV) proton flux observed by GOES16 is expected to persist at Background levels. The M1.4 flare from the current UTC morning is now perhaps sufficiently long ago that there is now unlikely to be any additional risk of a proton enhancement in the near-Earth environment.

This means that there remains a daily Slight Chance of flux levels rising in response to any significant flaring, particularly as AR3423 continues to move across the western solar hemisphere, along with AR3429 doing so towards the end of the forecast period.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES 16 proton flux



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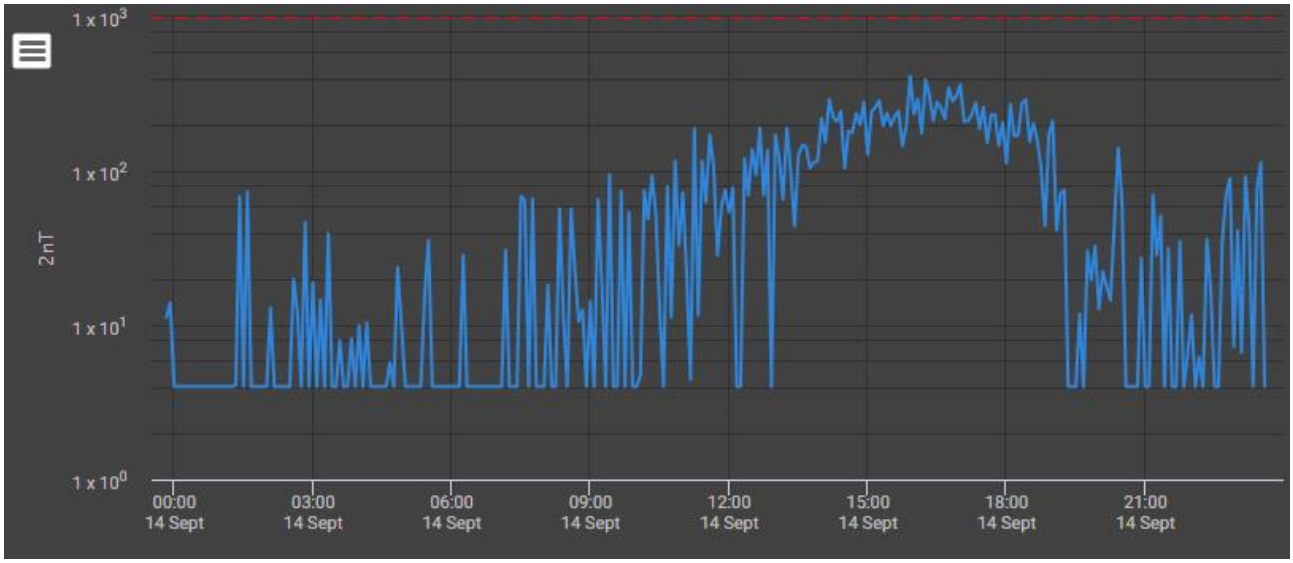
High Energy Electrons Event (≥ 2MeV):
High energy (greater than 2 MeV) electron flux observed by GOES16 is expected to remain generally at Normal Background levels through much of the period. The rationale for this is the succession of fast winds should give a sustained period of elevated geomagnetic activity that will serve to compress the Van Allen belt inside GEO and lead to an apparent decline in populations. This will likely continue to be the case into Day 3 (16 Sep) with the expected CME arrival, with any electron response unlikely until later Day 3 or into Day 4 (17-18 Sep) after this passes and coronal influences ease.

The associated 24-hour fluence will most likely remain below the Active (1e8 integrated pfu) threshold for much of the period, however there is perhaps a Slight Chance by the end of the UTC weekend in a late recovery in fluence. MOSWOC REFM is considered to be giving good guidance in the near term, with current coronal holes likely to deliver a similar response to last pass, although the main period of interest is the 72 to 96-hour period, which falls outside REFM's range.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	10	10	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: GOES 16 Eectron flux



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